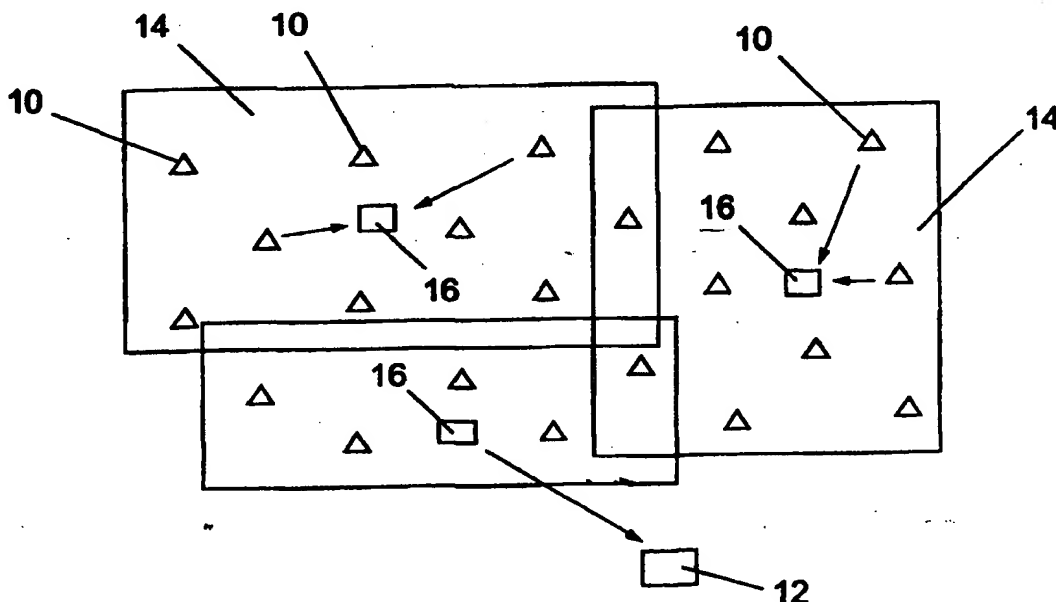




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : G01V 1/22	A1	(11) International Publication Number: WO 98/18022 (43) International Publication Date: 30 April 1998 (30.04.98)
<p>(21) International Application Number: PCT/GB97/02924</p> <p>(22) International Filing Date: 23 October 1997 (23.10.97)</p> <p>(30) Priority Data: 9622044.7 23 October 1996 (23.10.96) GB 9715967.7 30 July 1997 (30.07.97) GB</p> <p>(71) Applicant (for all designated States except US): VIBRATION TECHNOLOGY LIMITED [GB/GB]; Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): PARK, William, Pentland [GB/GB]; Vibration Technology Limited, Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB). SMITH, John, Grant, Flavell [GB/GB]; Vibration Technology Limited, Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB). WHELAN, John, Christopher [GB/GB]; Vibration Technology Limited, Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB). HAMILTON, David, James [GB/GB]; Vibration Technology Limited, Scion House, Stirling University Innovation Park, Stirling FK9 4NF (GB). SANDHAM, William, Alexander [GB/GB]; Vibration Technology Limited, Scion</p>		<p>House, Stirling University Innovation Park, Stirling FK9 4NF (GB).</p> <p>(74) Agent: MURGITROYD & COMPANY; 373 Scotland Street, Glasgow G5 8QA (GB).</p> <p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>

(54) Title: SEISMIC ACQUISITION SYSTEM USING WIRELESS TELEMETRY



(57) Abstract

A seismic acquisition system divides a survey terrain into a number of cells (14) each containing a cell access node (16) and a number of geophone units (10). The geophone units (10) transmit data in digital form to the respective cell access node (16) by wireless telemetry, and the cell access nodes (16) forward the data to a central control (12) by broadband channels.

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1 **SEISMIC ACQUISITION SYSTEM USING WIRELESS TELEMETRY**

2

3 This invention relates to seismic acquisition using
4 geophones.

5

6 It is well known to conduct a geophysical survey of a
7 land area by using an array of geophones in conjunction
8 with either a succession of explosions or a continuous
9 vibration applied to the ground by a vibratory
10 apparatus.

11

12 Although the results obtained are valuable,
13 conventional techniques are logistically slow, labour
14 intensive, and costly. It is necessary to deploy a
15 large number of geophones on a grid which has been
16 previously surveyed. Each geophone string is
17 individually wired to a central control unit. As the
18 survey progresses, geophones in the rear must be
19 disconnected, repositioned at the front, and
20 reconnected. This procedure is extremely laborious,
21 and the complexity of the connections gives a high
22 probability of error. The scale of the problem will be
23 understood when it is realised that a typical 3D
24 seismic array involves up to 750 km of cabling.

25

1 An object of the present invention is to provide a
2 means to simplify these procedures, and thus to reduce
3 the time and cost of the survey by a significant
4 factor.

5
6 Accordingly, the invention from one aspect provides a
7 seismic acquisition system comprising a multiplicity of
8 geophone units which, in use, are arranged in an array
9 across a survey terrain; each geophone unit comprising
10 means for deriving digital data representative of
11 seismic movement of the earth's surface at the geophone
12 location, and wireless telemetry means adapted to
13 receive command signals from a central control and to
14 transmit said digital data to the central control on
15 command.

16
17 In a preferred form of the invention, the terrain is
18 divided into a number of cells each of which contains a
19 number of geophone units and a cell access node. The
20 geophone units in a given cell communicate with the
21 respective cell access node using wireless telemetry at
22 a given frequency, with different frequencies used in
23 adjacent cells.

24
25 The cell access nodes may communicate with the central
26 control by radio, or by cable or fibre optic link.

27
28 The communication within each cell is preferably high
29 frequency (most preferably 2.4 GHz band) low power.
30 This permits a limited number of frequencies to be re-
31 used across the terrain.

32
33 The means for deriving said digital data may comprise
34 an analog geophone measuring velocity, coupled to an
35 analog-to-digital converter.

36

1 Each of the geophone units is preferably provided with
2 a memory for short term storage of said data, and for
3 permanent storage of a unique code identifying that
4 geophone unit.

5
6 Preferably, each of the geophone units has a
7 preamplifier and preamplifier control means remotely
8 operable from the central control. The preamplifier
9 control means may be operable to control the gain
10 and/or an operating time window of the preamplifier as
11 a function of the distance of that geophone unit from
12 the location of the seismic signal source being
13 monitored, and/or as a function of time.

14
15 Each of the geophone units may additionally have its
16 unique code physically embodied internally or
17 externally, or electronically tagged on a
18 microprocessor forming part of the geophone unit, or as
19 an external display for example in the form of a
20 machine readable bar code, all of which can be read by
21 wireless method using existing hardware.

22
23 The wireless telemetry means is preferably digital, and
24 may comprise a dedicated wireless system, or may be
25 provided by a cellular wireless system.

26
27 From another aspect, the invention provides a method of
28 conducting a seismic survey in which a number of
29 geophone units are positioned in an array across a
30 terrain of interest, a seismic signal (or a series of
31 seismic signals) is generated to produce seismic data
32 collected by the geophone units, the data for each
33 geophone unit is stored at the geophone unit, and said
34 data is transferred to a central location using
35 wireless telemetry, at the same time or at a later
36 time.

1 An embodiment of the present invention will now be
2 described, by way of example only, with reference to
3 the drawings, in which:

4

5 Fig. 1 is a schematic view of a seismic survey
6 system;

7 Fig. 2 is a block diagram illustrating one form of
8 geophone unit for use in the system; and

9 Fig. 3 is a schematic view of a survey area
10 illustrating radio frequency allocation; and
11 Fig. 4 is a block diagram of a central control
12 used in the system.

13

14 Referring to Fig. 1, a seismic survey across a
15 "prospect" or area of terrain of interest is conducted
16 by positioning a number of geophone units or remote
17 acquisition units (RAUs) 10 at known locations,
18 typically in a regular array. In the system of the
19 present invention, each RAU 10 can receive signals from
20 and transmit signals to a central control unit (CCU) 12
21 using wireless telemetry.

22

23 The array may be divided up into cells as indicated at
24 14 each with a transmitter/receiver or cell access node
25 (CAN) 16 acting as a relay between the RAUs 10 and the
26 CCU 12. This division may be required by the nature of
27 the terrain, but is advantageous in any event since it
28 allows the use of low power in the RAUs 10, thus
29 reducing size and cost.

30

31 Fig. 2 illustrates an individual RAU 10 which may be
32 used in the system of Fig. 1. The RAU 10 in Fig. 2
33 uses a single conventional geophone or string(s) of
34 geophones to provide velocity information at 20 in
35 analogue form to an analogue to digital convertor 22
36 via a preamplifier and filter stage 21. The digitised

1 information is stored at 24 for forwarding to the CAN
2 16 via a transmitter/receiver 26 in accordance with
3 control signals received from the CAN 16. These
4 control signals and the forwarding of the digital
5 information are by means of any suitable proprietary
6 protocol.

7
8 The RAU 10 also comprises a power supply 28 and control
9 circuitry 30. The power supply 28 suitably comprises
10 rechargeable or disposable batteries and preferably
11 also a solar panel.

12
13 Each of the RAUs 10 is identified by a unique code
14 which may be stored in a dedicated area of the store 24
15 as indicated at 24a.

16
17 The control circuitry 30 controls operation of the
18 preamplifier 21 in two ways.

19
20 First, the gain of the preamplifier 21 is adjusted as a
21 function of distance of the particular RAU 10 from the
22 location of the seismic signal source; this provides
23 more sensitivity at further distance from the source.
24 This adjustment may suitably be made and changed as the
25 location of the source is changed, the RAUs being
26 stationary.

27
28 Secondly, the gain may also be varied with time as the
29 return from the seismic signal source decays, with more
30 preamplification being used to boost the signal as it
31 decays. For example, an RAU close to the seismic
32 signal source could be set to have an initial gain of
33 2^0 which is used for the first second of the signal and
34 is increased to 2^1 , 2^2 and 2^3 for each successive
35 second, whereas a distant RAU may be set with an
36 initial gain of 2^4 , increasing to 2^5 , 2^6 and 2^7 .

1 These two factors are programmable from the CCU 12.

2

3 The control circuitry 30 also controls the operation of
4 the digital wireless telemetry such that the power
5 output is variable, allowing the number of RAUs 10
6 reporting to any given CAN 16 and the distance of any
7 RAU 10 from any given CAN 16 to be programmed, allowing
8 the design of the seismic surveys to be flexible.

9 These factors are also programmable from the CCU 12.

10

11 In operation, the CCU 12 transmits a signal to
12 indirectly activate the RAUs 10 prior to initiation of
13 the seismic signal source and each unit then stores
14 data for a given period after that signal. The CANS 16
15 poll their respective RAUs 10 causing each RAU to
16 transmit its stored information preceded by its
17 identity code. By using different frequencies in the
18 various cells 14, polling can proceed simultaneously in
19 each cell, with the CANS 16 communicating with the CCU
20 12 via a small number of broadband wireless links, or
21 data cable or fibre optic links.

22

23 In a modification, RAUs may be used which each comprise
24 two or more geophones operating with a single memory,
25 control circuitry and transmitter/receiver.

26

27 The shape and size of the cells is determined by the
28 range of the wireless transceiver, the terrain,
29 obstructions, and to a lesser extent the weather. The
30 RAUs in a given cell operate on one set of radio
31 frequencies. Adjacent cells operate on different
32 frequencies.

33

34 The telemetry system is able to re-use frequencies in
35 non-adjacent cells. Fig. 3 illustrates this with
36 reference to a survey area crossing a ridge (indicated

1 by contour lines 37). Given that the radio
2 transceivers have a limited range, once outside that
3 range a given frequency can be re-used in another cell.
4 Thus radio frequencies can be re-used on a rolling
5 basis to minimise the number of frequencies required by
6 the system.

7
8 The radio system may particularly operate in the 2.4
9 GHz band at low power. High frequencies of this order
10 decay quickly with increasing distance, which allows a
11 limited number of frequencies to be used for an
12 unlimited number of cells. The 2.4 GHz band is
13 particularly preferred as this is a licence-free band
14 in many territories.

15
16 In the event of a CAN receiving signals from a number
17 of different cells, the system software can de-
18 duplicate the signals by deleting the weaker signals.

19
20 A suitable resolution will be obtained by each geophone
21 generating 24-bit information at a repetition rate of
22 500 Hz (2ms sample rate). The bandwidth requirement of
23 the polling system may be reduced by using known data
24 compression techniques in the RAUs 10 or CANs 16.

25
26 As one example, for a 24-bit sample at 2ms intervals,
27 the maximum data rate per geophone unit would be 12
28 kbits/s, and for a sector with eighty geophone units,
29 the sector base station would have a maximum data rate
30 of 1 Mbits/s. There are available low cost
31 radiotelemetry modules suitable for this data rate; for
32 example, the "Prism" radio chipset from Harris
33 Semiconductor Limited can handle up to 4 Mbit/s.

34
35
36 Fig. 4 shows one suitable form of CCU. Data is

1 captured on a commercially available seismic
2 acquisition recording unit 44 of known type. This
3 issues timed shot commands at 46. Each shot command
4 causes a sync pulse generator 48 to generate a sync
5 pulse 1 to activate the geophones, and a series of
6 timed sync pulses 2₁ to control the polling. The sync
7 pulses are encoded and transmitted at 50 via a
8 transmit/receive switch 52, which also gates incoming
9 data signals to a receiver and decoder 54 to supply
10 data for the recording unit 44.

11

12 In a modification of the CCU, the sampling interval is
13 reduced stepwise in time. As one example, instead of
14 sampling every 2 ms for a total of 4s, the sampling
15 rate would be every 2 ms for the first second, every 4
16 ms for the next second, every 6 ms for the third
17 second, and every 8 ms for the fourth second. The
18 reason for this is that high frequency information is
19 attenuated with time in comparison with low frequency
20 information, and therefore the further one is away in
21 time from the input event the less high frequency there
22 is to be measured and the sampling rate can be reduced.

23

24 It is of course necessary for the CCU 12 to have
25 information defining the position of each of the RAUs
26 10. This may be achieved, as is currently done with
27 wired systems, by securing the RAUs 10 at positions
28 previously marked by conventional surveying. To assist
29 in loading information defining which RAU is at which
30 location, each RAU may conveniently be provided with an
31 external, machine-readable label such as a conventional
32 bar code with that unit's unique identity code. The
33 personnel installing the units can thereby enter the
34 location number and the corresponding geophone code in
35 a simple manner into portable recording apparatus for a
36 subsequent downloading into the central control 12.

1 As an alternative, each RAU could include an electronic
2 positioning means which would enable the RAUs to be
3 positioned on the terrain without a preliminary survey
4 with the position of each RAU thereafter being
5 established by the CCU 12 by polling location data from
6 the RAUs 10. Such electronic positioning means could
7 be provided by a GPS system. Positional accuracy can
8 be improved by use of Differential GPS (DGPS). Rather
9 than incurring the expense of DGPS in each RAU, since
10 the RAUs are at fixed locations the positional
11 information can be loaded into the RAU when it is
12 installed; conveniently this could be done by infra-
13 red, radio or any other suitable means of short range
14 data transfer linking from a portable DGPS apparatus
15 which also includes the bar code reader.

16
17 Alternatively, the position of the CAN for each cell
18 could be fixed by a GPS receiver in the CAN, and the
19 relative position of each RAU with respect to its CAN
20 determined by a relatively simple local system.

21
22 It is likely that a dedicated wireless telemetry system
23 would require to be used, with one frequency to carry
24 commands from the CCU 12 indirectly to the various RAUs
25 10 and a number of separate frequencies to carry data
26 in reverse. In certain locations however it might be
27 possible to use systems similar to cellular telephones
28 for both commands and data.

29
30 Other modifications and improvements may be made to the
31 foregoing within the scope of the present invention, as
32 defined in the following claims.


33

CLAIMS

1. A seismic acquisition system comprising a multiplicity of geophone units arranged in an array across a survey terrain, wherein each of said geophone units comprises means for deriving digital data representative of seismic movement of the earth's surface at the geophone location, and wireless telemetry means adapted to receive command signals from a central control and to transmit said digital data to said central control on command.
2. A seismic acquisition system as claimed in Claim 1, wherein said survey terrain is divided into a number of cells, each of which contains a plurality of geophone units and a cell access node.
3. A seismic acquisition system as claimed in Claim 2, wherein said plurality of geophone units within a given cell communicate with said cell access node using said wireless telemetry at a given frequency, with different frequencies used in adjacent cells.
4. A seismic acquisition system as claimed in Claim 3, wherein said communication within each cell is high frequency (2.4 GHz band) low power.
5. A seismic acquisition system as claimed in Claim 3 or Claim 4, in which a given frequency is used in a number of non-adjacent cells across the terrain.
6. A seismic acquisition system as claimed in any of

- 1 Claims 2 to 5, wherein said cell access nodes
2 communicate with said central control by radio, by
3 cable, or by fibre optic link.
4
- 5 5. A seismic acquisition system as claimed in Claims
6 3 and 4, wherein said communication within each
7 cell is high frequency (2.4 GHz band) low power.
8
- 9 7. A seismic acquisition system as claimed in any
10 preceding Claim, wherein said means for deriving
11 digital data comprises an analog geophone
12 measuring velocity, coupled to an analog-to-
13 digital convertor.
14
- 15 8. A seismic acquisition system as claimed in any
16 preceding Claim, wherein said geophone units are
17 provided with a memory for short term storage of
18 said data, and for permanent storage of a unique
19 identification code.
20
- 21 9. A seismic acquisition system as claimed in any
22 preceding Claim, wherein each of said geophone
23 units has a preamplifier and preamplifier control
24 means.
25
- 26 10. A seismic acquisition system as claimed in Claim
27 9, wherein said preamplifier control means is
28 operable to control the gain and/or an operating
29 time window of said preamplifier as a function of
30 the distance of said geophone unit from the
31 location of the seismic signal source being
32 monitored, and/or as a function of time.
33
- 34 11. A seismic acquisition system as claimed in Claim
35 8, wherein each of said geophone units has its own
36 unique code physically embodied internally or

1 externally, or electronically tagged on a
2 microprocessor forming part of said geophone unit,
3 or as an external display such as a bar code.
4

5 12. A seismic acquisition system as claimed in any
6 preceding Claim, wherein said wireless telemetry
7 means is digital. 
8

9 13. A method of conducting a seismic survey, wherein a
10 plurality of geophone units are positioned in an
11 array across a terrain of interest, a series of
12 seismic signals is generated to produce seismic
13 data collected by said geophone units, the data
14 for each of said geophone units is stored at said
15 geophone unit, and said data is transferred to a
16 central location using wireless telemetry, at the
17 same time or at a later time.
18

19 14. A method according to Claim 13, in which said
20 survey terrain is divided into cells, each of
21 which contains a plurality of geophone units and a
22 cell access node, said data being transferred from
23 each geophone unit to its respective cell access
24 node by wireless telemetry, and from each cell
25 access node to said central location by radio, by
26 cable, or by fibre optic link.
27

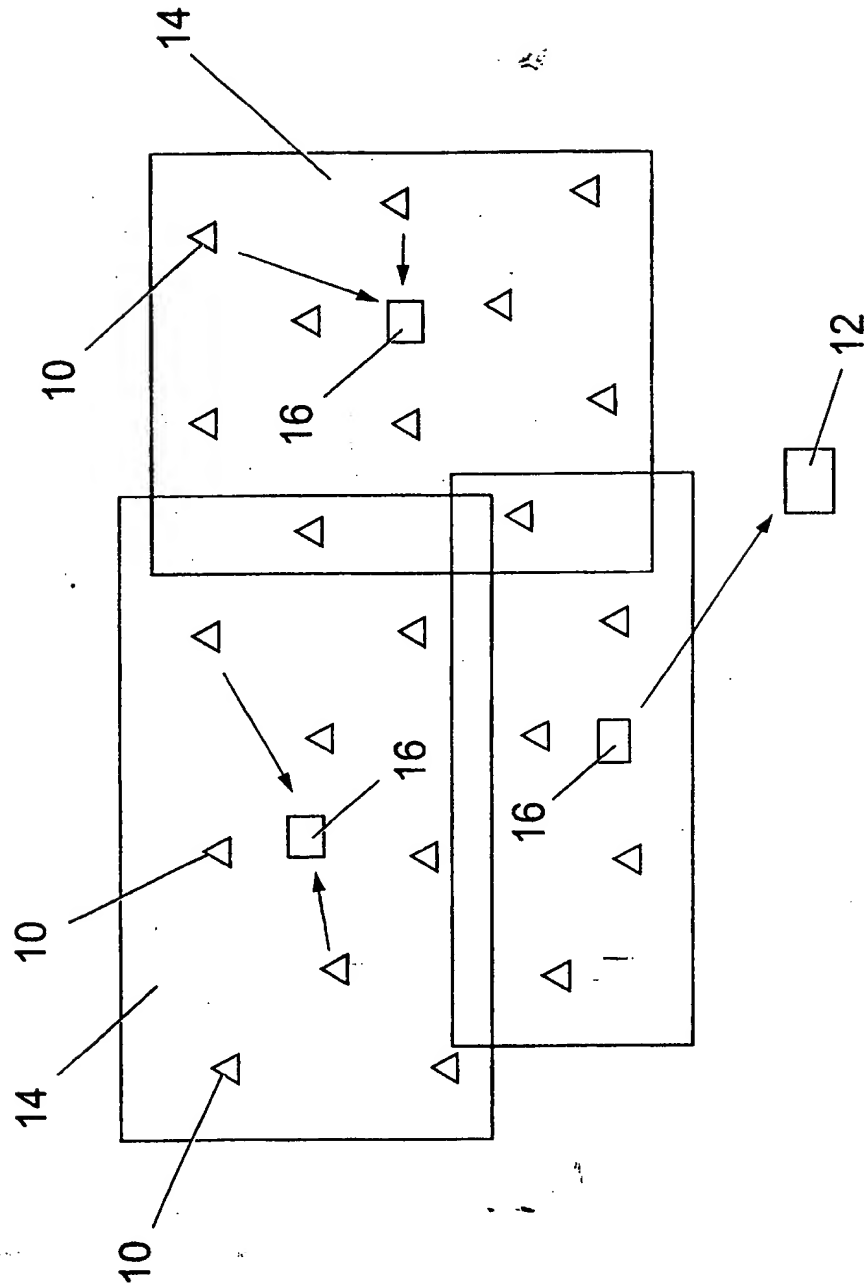
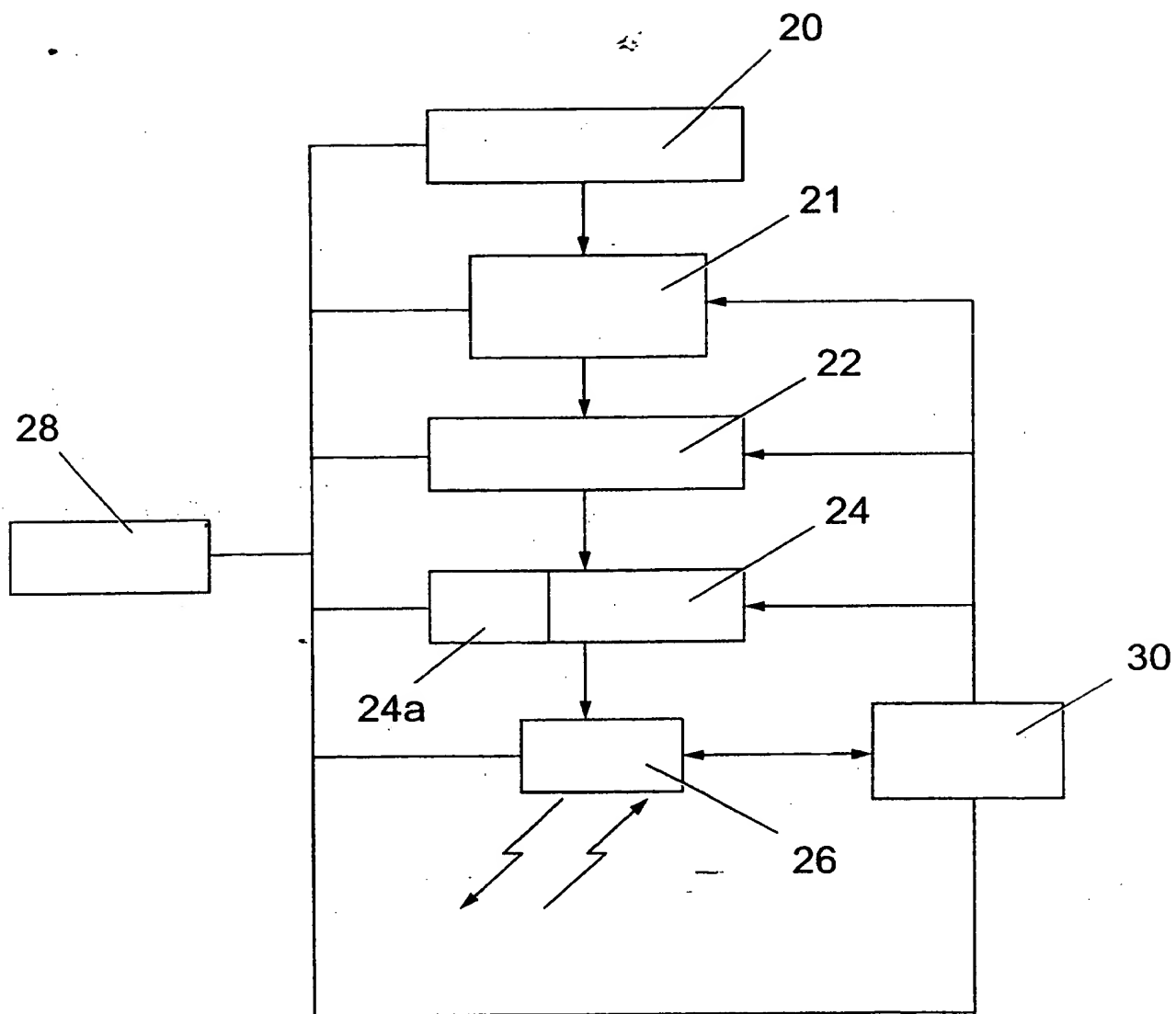
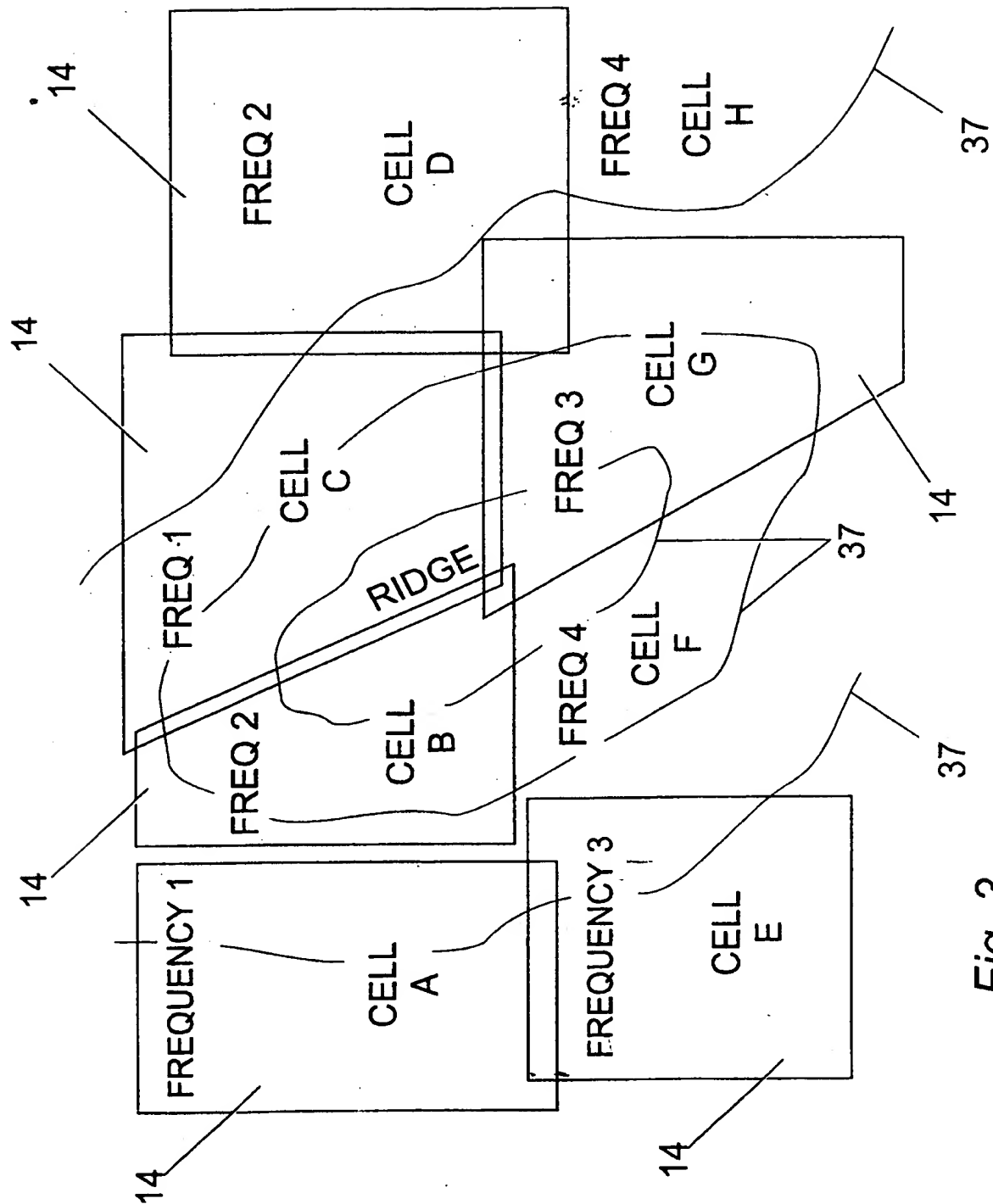


Fig. 1

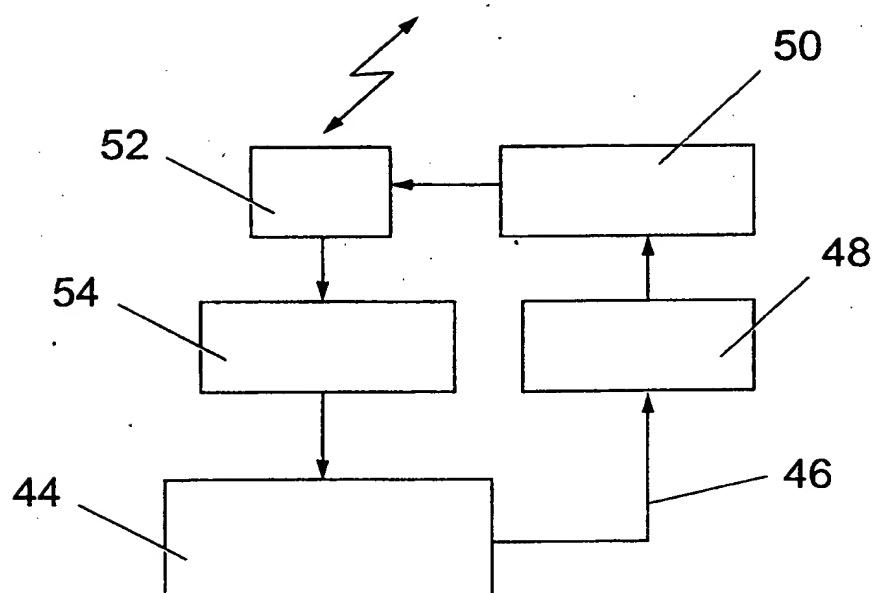
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*Fig. 2*

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*Fig. 4*

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 97/02924

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01V1/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 815 044 A (DECONINCK BERNARD ET AL) 21 March 1989 see abstract see column 3, line 47 - line 53 see column 4, line 34 - line 68 see column 7, line 62 - column 8, line 47	1-3,6-8, 11,13,14
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A	EP 0 646 809 A (INST FRANCAIS DU PETROL) 5 April 1995 see column 1, line 30 - line 50 ---	9,10
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Date of the actual completion of the international search

20 February 1998

Date of mailing of the international search report

04/03/1998

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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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